CHAPTER II
REVIEW OF LITERATURE

2.1 HISTOMORPHOLOGY

2.1.1 Oviduct during follicular and luteal phases

Hackett and Hafs (1969) observed the histological and biochemical changes in fallopian tube of Holstein heifers during estrus cycle. They found that on 20th day of estrus cycle maximum epithelial height in oviduct. Which is declined in proestrus. These changes in the oviductal cells height were influenced by progesterone. They further suggested that the morphological changes in epithelium were due to differential responsiveness to the ovarian steroid hormones both within and among the tubular genitalia.

Uhrin (1983) studied microscopic structure of the epithelium of the oviducts in cows during the estrus cycle. He noted that the mucous membrane was covered with ciliated and secretory cells with basal cells at the basal membrane. He found that the counts of ciliary cells varied during the sexual cycle, and reached maximum (up to 68%) during estrus. About 13% of cells lose cilia during metestrus and at the beginning of diestrus. Reciliation occurred during proestrus. Light and dark ciliary cells could be discerned by the staining of cytoplasm and by the density of nuclei. He stated that the secretory cells were light and dark cells wedge shaped and rod-shaped cells. He found increase in the volume of secretory cells during metestrus and diestrus and the volume of ciliary cells increases during proestrus and heat. The volume of nuclei decreased in metestrus and mainly in diestrus. PAS positive granules occurred in the cytoplasm of secretory cells, mainly during metestrus. Ptyalin-resistant polysaccharides, besides glycogen, were detected in the cells.

Singh and Prakash (1990) studied the histological and histochemical changes in the ampulla of goat. They found that the epithelium was simple columnar type with ciliated and non-ciliated cells. Ciliated cells became shortened and lost their cilia during late luteal phase. They could not differentiate the epithelium into ciliated and non-ciliated type. They further noted some migratory cells in epithelium. They opined that progesterone secreted during the luteal phase though accelerated the ciliary beats, might also favor loss of cilia later in the cycle. The inner layer of tunica mucosa-submucosa was again subdivided into an outer fibroelastic layer and an inner
epithelial layer. Tunica muscularis was composed of smooth muscle fibers arranged in circular fashion. A few bundles on periphery were oriented in an oblique or longitudinal direction but a distinct outer longitudinal layer was not seen. This arrangement was believed to play an important role in the transport of ovum by their contractions in goat. They observed that tunica serosa consisted of a thin layer of loose connective tissue containing predominantly collagen and elastic fibers. They found positive PAS reaction for glycogen and Alcian Blue PAS reaction for mucopolysaccharides.

Natarajan et al. (2003) studied the histological and histochemical structure of the oviduct of the buffalo (*Bubalus bubalis*) at different reproductive stages. The mucosa of infundibulum during follicular phase was highly branched with primary, secondary and tertiary folds occupying greater part of lumen. In luteal phase, tertiary folds in mucosal infundibulum were absent and not completely occupying the lumen. During follicular phase, secretory material was noticed within apical portion of epithelial cells and also cytoplasmic projections were seen from the surface of cells of ampulla, cytoplasmic protrusion and nuclear extrusion were distinct in ampulla. They noted more lymphocytic infiltration in ampulla during luteal phase and also noticed mast cells in the subepithelial layer. No cyclic changes were noticed in epithelial cells of isthmus. The PAS-positive material revealed metachromasia and protein, suggesting carbohydrate-protein complex nature of secretion from epithelial cells of the oviduct.

Steinhauer et al. (2004) studied morphological changes and proliferative activity in the oviductal epithelium during hormonally defined stages of the estrous cycle in the bitch with regard to the part of the oviduct. They noted that, the oviductal epithelium was highly differentiated under the influence of estrogen during late follicular phase. Lighter stained ciliated cells with apically located nuclei were easily distinguishable from basophilic secretory cells with apical cytoplasmic protrusions. Cell height and percentage of ciliated cells were significantly higher than in anoestrus. The percentage of ciliated cells and cell height were significantly lower during late follicular phase. Further signs of dedifferentiation consisted of a loss of cilia, a pinching off of the apical cytoplasm as well as the presence of debris and macrophages within the oviductal lumen. In the caudal isthmus, hormone-dependent variations in cellular morphology were less distinct. Changes in cell height were minimal and did not differ significantly throughout the estrous cycle. Hypertrophic
cells with large nuclei were predominantly present at these sites, but did not consistently demonstrate signs of ciliation or secretion. They stated that overall proliferative activity was generally very low or might occur within a relatively short period of time. They reported that estrogen caused hypertrophy and differentiation, whereas progesterone induced gradual dedifferentiation or regression of the oviductal epithelium. Furthermore, they revealed clearly visible changes in the morphology of the tubal epithelium during the estrous cycle.

Jiwakanon et al. (2005) conducted studies on morphological changes and infiltration by cells of the immune system in the sow endosalphinx at different stages of the estrous cycle and at anoestrus. They noted lower degree of morphological changes in the isthmus compared with ampulla and infundibulum. In ampulla and infundibulum, pseudostratification, mitotic activity and secretory granules of the epithelium were high at prooestrus/oestrus. Cytoplasmic protrusions of epithelial cells with some extruded nuclei were prominent in ampulla and infundibulum at all stages except for estrus and early dioestrus. They observed that lymphocytes were the predominant immune cells in the epithelial layer. Neutrophils were only occasionally found and mainly in the infundibulum. In the subepithelial connective tissue layer, the two most commonly observed immune cell types were lymphocytes and plasma cells. In the oviduct, the morphology differed in ampulla and infundibulum with oestrous cycle stages, which indicates an effect by ovarian steroid hormones. They stated that the immune cell infiltration was less influenced by cyclic changes. However, the immune cell infiltration (in the connective tissue) in the upper part, especially infundibulum, differed significantly from the one in the lower part, isthmus, indicating different immune functions within various parts of the oviduct.

Eurell and Frappier (2006) describe that the oviduct are bilateral, tortuous structures that extend from the ovary to uterus, convey ova, spermatozoa and zygote. Based on the microscopic appearance of the oviduct and the structure of the lining epithelium, oviduct was divided into three segments namely infundibulum, ampulla and isthmus. They further stated that the wall of the oviduct consisted of tunica mucosa including lamina epithelialis and lamina propria, tunica submucosa, tunica muscularis and tunica serosa. The epithelium was simple columnar or pseudostratified columnar with motile cilia on most cells. Both ciliated and nonciliated or secretory cells types possessed microvilli. In cow, ciliated and secretory cells occurred more commonly in the cranial end of the uterine tube during estrus. During the luteal phase,
the secretory cells became taller than the ciliated cells. Their secretion provides the ovum and zygote with the necessary nutrients. The mucosa was continuous with the submucosa because the lamina propria was absent. The submucosa consisted of loose connective tissue with many plasma cells, mast cells and eosinophills. The tunica mucosa-submucosa of the ampulla was highly folded, especially in sows and mares. Approximately 40 primary longitudinal folds were present in the ampulla, each with secondary and tertiary in cows. The secondary and tertiary folds gradually disappear in the isthmus with increasing distance from the ampulla, and at the isthmus-uterus junction, only four to eight primary folds and no secondary or tertiary folds were present.

They further stated that the tunica muscularis consisted mainly of circular smooth muscle bundles with occasional longitudinal and oblique muscle bundles also found. The muscle layer gives off radial strands into the mucosa. In the infundibulum and ampulla, the tunica muscularis was thin and composed of an inner circular layer and a few outer longitudinal bundles of smooth muscle. In the isthmus, the inner muscle layers were prominent and blend with the uterine circular muscle. Tunica serosa was present and consisting of many blood vessels and nerves.

Samuelson (2007) noted that oviduct was internally lined by pseudostratified columnar epithelium in cow and sow. He further observed that the height of the epithelial cells shorten as the uterine tube progress towards the uterus. He stated that cilia of epithelial cells as well as smooth muscle of uterine tube play a role in moving ova to the uterus. He further stated that the nonciliated cells are believed to be secretory and provide nutritional support for the gametes moving through uterine tube which also help the maturation process of spermatozoa. As oocytes are released during ovulation, the nonciliated columnar cells become metabolically more active and typically increase in their height being sometimes referred to as peg cells. He observed that the loose connective tissue of lamina propria was composed primarily of small collagen and elastic fibers that were interspread with fibrocytes, occasional lymphoid cells and less frequent mast cells. He stated that cells with extensive amount of condensed chromatin tend to be either largely inert or involved in only a major metabolic activity.

Sharma and Rita (2007) studied the topographic and ultrastructural changes in the infundibulum of goat oviduct during follicular and luteal phases and observed that the oviductal epithelium of goat revealed marked cyclic variations in the topography
and fine structure. They observed the characteristic pattern of changes in the number, height and branching of the mucosal folds and relative frequency of ciliated and secretory cells during both the phases of the oestrous cycle. The number of non-ciliated cells were higher than the ciliated cells during the luteal phase. These non-ciliated cells showed large finger like cytoplasmic protrusions. Secretory cells appeared as collapsed envelopes (ghost cells) were interspersed at some places. In the follicular phase presence of low electron dense cytoplasm in the ciliated cells were the characteristic feature. Densely stained secretory cells possessed small secretory granules with dense homogeneous matrices.

Tienthai et al. (2008) reported that the degree of the histological and morphometric changes was high in the ampulla and infundibulum compared with that of the isthmus at both follicular and luteal phases of the estrous cycle in Thai swamp buffalo. In the follicular phase, ciliated cells were predominating in the infundibulum and ampulla, cytoplasmic protrusions of the epithelial cells with extruded nuclei were prominent at the luteal phase and disappeared during the follicular phase. The epithelial cell height significantly decreased in the infundibulum and ampulla from the follicular to luteal phases, but not in other regions. The number of intraepithelial leukocytes was significantly different between the stages of the estrous cycle.

Tienthai et al. (2009) observed that there were two distinct cell types, ciliated and secretory cells and were distinguished by light microscopy in the sections stained with periodic acid Schiff (PAS). In infundibulum and ampulla ciliated cells were predominating during follicular phase and secretory cells were predominated in luteal phase. The features of these cells were shown various degrees of cytoplasmic protrusion. No difference in the morphology of the isthmic and utero tubal junction epithelial cells was observed between the follicular and luteal phases.

Ayen et al. (2012) observed that in the oviduct of Azarbaijan buffaloes the epithelium of folds was composed of simple columnar and pseudostratified in some areas, which contains ciliated and secretory cells. Ciliated cells are more identified during follicular phase in the infundibulum and gradually decrease in the ampulla towards isthmus.

Bacha and Bacha (2012) described the wall of the oviduct comprised of serosa, muscularis, lamina propria and epithelium in domestic animals. In isthmus part thickest layer was tunica muscularis formed by circular smooth muscle with longitudinally arranged smooth muscle external to it. The lining epithelium of oviduct
was ciliated. In part, the epithelium of ruminant and sow was pseudostratified. The mucosa was thrown into longitudinal folds with less folding occurring in the isthmus than in the ampulla. They observed extrusion of nuclei from the epithelial cells in infundibulum of oviduct in cow. In infundibulum of cow, they noted that mucosa was highly folded whereas muscularis was relatively thick. In isthmus of mare, they noted that the mucosa of the isthmus had fewer folds than any other part of oviduct. The muscularis was thickest in this part of oviduct.

Katare et al. (2015) found in adult goats that the height and number of primary and secondary folds decreased from infundibulum to isthmus, however, they were more during follicular phase. The epithelial lining was mainly pseudostratified columnar with more number of ciliated cells during follicular phases but secretory cells were more during luteal phase. Stroma was formed of loose connective tissue and rich in blood vessels, collagen and reticular fibres. Elastic fibres were sparse and seen mainly in the wall of blood vessels during both phases. The cyclic changes were more pronounced in the infundibulum and ampulla of the oviduct. Tunica muscularis containing most of the circularly arranged muscle fibers which were loosely arranged. Thickness of tunica muscularis was more during follicular phase than the luteal phase.

Saleem et al. (2016) observed that the wall of the oviduct of Bakerwali goat was four layers the tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa. The tunica mucosa was consist of lamina epithelialis and lamina propria. Due to the absence lamina muscularis mucosae Lamina propria and tunica submucosa were blended together and formed propria submucosa. Throughout the length of the oviduct tunica mucosa was characterized by presence of longitudinal folds. Folds are primary, secondary and tertiary. Infundibulum and ampulla were lined by pseudostratified ciliated columnar epithelium whereas isthmus was lined by non-ciliated pseudostratified columnar epithelium during the follicular and luteal phase of estrus cycle. They also observed the simple tubuloalveolar oviductal glands in tubal part of all the segments of oviduct the number of these glands increased from infundibulum to isthmus. The glandular diameter, epithelial height and nuclear height is higher in luteal phase. The propria submucosa composed of loose connective tissue, rich in blood vessels, collagen fibres and elastic fibres. Elastic fibres were seen mainly in the wall of blood vessels. They found that the thickness of tunica mucosa and tunica muscularis increases towards the isthmus and was significantly higher in
luteal phase of estrus cycle whereas height of epithelium was significantly higher in luteal phase but decreased towards the layer of muscles in the terminal part of isthmus.

2.1.2 Uterus during follicular and luteal phases

Dukes (1970) described the cyclic changes in the endometrium which were designed to prepare the uterus to receive the blastocyst for successful implantation. The endometrial glands of cattle were branched, coiled and tubular lined with columnar epithelium except in the caruncular area. These glands opened on the endometrial surface. He further observed that, due to corpus luteum development progesterone level increased which was responsible for development of more coiled, complex of gland and regressed at about 16th day. There was maximum height of glandular epithelial cells at about 8th day of the cycle. The endometrial epithelial cells were having maximum height during estrus and after profuse secretion two days post estrus, the cells were low cuboidal but there was again rise in the height between 9th to 12th day of cycle.

EL-Sheikh and Abdelhadi (1970) studied the histology of the reproductive tract in the Egyptian buffalo. The endometrium consisted of four area as superficial pseudostratified columnar epithelial layer, a dense connective tissue (stratum compactum), stratum spongiosum where the uterine glands ramify and stratum basalis in which the uterine glands terminate. They found that the uterine glands were tubular and coiled, passed towards the surface, where they open. They also reported that the myometrium of the uterus in Egyptian buffaloes could be divided into three ill-defined areas as stratum submucosum, stratum vascularae and stratum subserosum. Further, they stated that stratum sumucosum was thicker than the stratum subserosum and stratum vasculare which consisted of many thick walled blood vessels.

El-Naggar and Fateh (1973) studied histological structure in 176 gravid and 10 non-gravid uteri of buffalo which were representing the various months of pregnancy. Measurements of the different layers of the uterine wall as well as the diameter of the uterine glands and the height of their lining epithelium were made on both gravid and non-gravid horns. The lamina epithelialis in the gravid horn became desquamated in the first three months of pregnancy and restored itself in horns containing fetus of 15 cm CVR length or more, i. e. in the beginning of the fourth month. Edema of the
endometrium was noticed at the fourth month and disappeared at the seventh month. The diameter of superficial and basal uterine glands in both the gravid and the non-gravid horns increased to a maximum at the ninth month. Generally the superficial glands possessed higher epithelium than the basal glands and the glands in the gravid horn had higher epithelium than in the non-gravid.

Sundaravadanan and Venkataswamy (1973b) studied the cyclic changes with regard to the thickness and vascularity of endometrium and growth of uterine glands in the follicular and luteal phases of the estrus cycle in bovines. In the follicular phase the surface epithelium was pseudostratified while in the inter-caruncular region it was of tall columnar type. The endometrium was thick, moderately vascular and edematous. The uterine glands were numerous and simple type. The myometrium was thick. The blood vessels in stratum vasculare were large and contained abundant elastic tissue. In the luteal phase, the surface epithelium of the inter-caruncular region was pseudo-stratified short columnar type. The endometrium and myometrium were not as thick as it was in follicular phase but it was compact and highly vascular. The uterine glands were numerous and highly tortuous with a wide lumen and opened on the surface. The blood vessels in stratum vasculare contained abundant elastic tissue. In smooth ovarian condition, the pseudo-stratified surface epithelium of inter-caruncular area was short columnar to cuboidal in appearance. Endometrium was less vascular and compact. The uterine glands were few and simple with narrow lumen.

Sundarvandanan (1974) studied the histological changes occurring in the bovine cervix and vagina during the follicular, luteal, senile, cystic and smooth ovarian conditions. In the follicular phase of the cycle, the cervical folds were long and extensively branched. The lining epithelium consisted of tall columnar cells, ciliated and secretory in type. Cytoplasm of many of the secretory cells was vacuolated and their nucleus was basal. Muscularis was thin and highly vascularised with large capillaries. The connective tissue was rich in elastic fibers. In the luteal phase, mucosa folds were short and less extensively branched. Lining epithelium was consisted of short columnar cells. Many of the secretory cells had compact cytoplasm and centrally placed nucleus. Muscularis was thick with a few small capillaries. Elastic fibers were scanty in the connective tissue. In the smooth ovarian condition, mucosal folds were short without branching. The lining epithelium was of low columnar type. Cytoplasm of many of the secretory cells was compact and the nucleus was centrally placed.
Fateh El-Bab and El-Naggar (1975) reported that the cervix of buffalo composed of mucosa, muscular layer and serosa. The mucosa were arranged in simple and branched primary, secondary and tertiary folds. The height of folds were maximum in the middle part and thicker in the caudal portion of cervix. The surface epithelium was simple columnar and changes to pseudostratified columnar at the base of primary folds, maximum epithelial height were observed during estrus. The cranial portion of cervix consist of thick layer of propria mucosa made up of elastic and reticular fibers. They found that the Elastic fibers were arranged around blood vessels, cervical glands and at base of secondary folds, while reticular folds form the core of secondary folds. They observed the simple branched tubular glands were present on cranial thirds of lateral wall. Muscular layer composed of smooth muscle fibers arranged in various direction and was thicker towards the external os, elastic fibers were present in between muscle bundles.

Heranjal et al. (1976) studied the histological changes in the reproductive tract of 15 healthy Indian she-buffaloes during various phases of estrus cycle having approximately same size, weight and age from the abattoir. Eight of the ovaries were in the follicular phase and seven in the luteal phase as revealed by histological examination. The endometrium was congested and edematous in the follicular phase. Glandular proliferation and dilatation increased significantly in the endometrium in the luteal phase. However, in one specimen extravasations of blood was evident on the surface of the uterus. The cervix and the vagina of the same animal showed blood tinged mucous. The increased in the vascularity began during proestrus and reached maximum approximately one day after estrus. When ovulation occurred, the estrogen level dropped rapidly resulting in the breaking down of the congested capillaries and small quantity of blood was discharged into the uterus. This blood mixed with the mucus at the cervical canal and passed on the floor of the vagina and was discharged as metestral bleeding. In the follicular phase, the cervical mucus was profuse in the cervix along with congestion and edema. These changes were much less in the luteal phase. The mucus was constantly secreted by cervical columnar cells which could be visible in both the phases of the estrus cycle. The excessive vascularity and edema of the cervix accompanied by profuse mucus discharge which was significant in the follicular phase.

Salisbury and Van Demark (1978) studied the changes in endometrium in cattle, which were more pronounced in the stroma and uterine glands than in the free
epithelial surface. The epithelial lining of the uterus was pseudostratified columnar type. They observed that, the height of the cells in relations to the cell nucleus vary with the period of the estrus cycle. There was greatest vascularity of the superficial stroma between 8 to 11 days post estrus. While the glandular coiling and hypertrophy was maximum between 8 to 12 days post estrus.

Heydon and Adams (1979) studied the histology of the cervix of 16 ewes, 16 female goats and 13 cows. They recorded that, in all three species the mucosa showed large folds, which were tallest and thickest in the cow and thinnest in the ewe. The folds varied in height, particularly within the cervix of cow and goat. The cervical folds were taller, more numerous and less regular in size in the cranial part of the cervix in all species. Small secondary indentations occurred in the cervical folds of the cow and goat and were particularly numerous and well developed in the cervix of the cow. In all the three species studied the cervix was found without glands.

Hafez (1980) studied the histological structure of uterus of the farm animals. The uterus was consisted of a thin outer layer, the perimetrium, middle thick myometrium which was composed of inner circular and outer longitudinal smooth muscle layers and an inner, the endometrium. The changes occurred in endometrium of uterus during the estrus cycle was responsible for developing the blastocyst and therefore play a major role in the reproduction process. The endometrium was a highly glandular structure consisted of an epithelial lining of the lumen, glandular layer and connective tissue. It varied in thickness and vascularity with changes in ovarian hormones throughout the estrus cycle and pregnancy. The uterine epithelium was lined by columnar epithelial cells. The caruncles consisted of connective tissue comparable to that of cortical stroma of the ovary. The deeper areas between the caruncles were rich in blood vessels without glands. The endometrial glands were simple branched tubular types that were more or less coiled, especially toward their ends. The glands possessed a lamellar connective tissue and were lined by simple or columnar ciliated epithelium. The density of glands varied with species, breed, parity and estrus cycle. The number of glands was higher in the horns than the mucosa adjacent to the cervix. During metestrus in the cow, the caruncles showed a pronounced capillary distension and bleeding but the epithelium remained intact. During pregnancy the muscular tissue underwent hypertrophy as well as hyperplasia. The serosa (perimetrium), the stratum musculare and the layer of longitudinal muscle were all continuations of the broad ligament, which invested and suspended the
uterus. The cervical wall consisted primarily of fibrous elastic and collagenous tissue and a small amount of muscle. The connective tissue was made up of fibrous constituents, mainly collagen fibers with rare reticular fibers.

Singh (1983) studied the histology and histochemistry of the uterus in buffalo during estrus cycle. He recorded that the endometrium consisted of the lamina epithelialis and the lamina propria. The epithelial lamina was composed of pseudostratified columnar epithelium varying in height according to different stages of the estrus cycle and the loci of the uterine cavity (cavum uteri). The lining epithelium of the cavum uteri consisted of pseudostratified columnar occasionally ciliated type. Their cytoplasm was homogenously eosinophilic. The apical border of these cells quite often showed modifications like striated borders, cilia or secretory blebs indicating their secretory or absorptive nature. The uterine glands were simple, coiled tubular type arising from the invaginations of the endometrial surface lining, which were unbranched but sometimes they were branched either in the middle or at the ends. Glands were less coiled in the superficial zone of the endometrium but comparatively more coiled in the deeper zones. The degree of coiling was varied with the stage of estrus cycle.

Uhrin (1984) studied microscopic changes in the glandular epithelium of cows during estrus cycle. There were greater structural changes in the cells of the glandular epithelium than that of luminal epithelium. In diestrus, the relative volume of mitochondria was dropped. The surface area of the granular endoplasmic reticulum and smooth membranes were recorded in diestrus.

Chavan (1987) studied the histological structure of the uterus of Murrah buffalo during diestrus stage and observed that the endometrium was consisted of single layer of the surface epithelium and highly cellular endometrial stroma. The surface epithelium was consisted of pseudostratified tall columnar cells. The endometrial stroma consisted of narrow layer of dense connective tissue and deeper layer of connective tissue. Caruncular area was consisted of dense connective tissue with numerous blood vessels. The endometrial stroma was consisted of uterine glands. The uterine glands were branched, coiled or straight tubular which were absent in caruncular area. The glandular epithelium was consisted of single layer of tall pseudostratified columnar cells and in some glands simple columnar cells were also noticed. Glandular cells possessed cilia and these cilia were more in number as compared to cilia of surface epithelial cells. Glands were wider towards epithelial
surface and narrower towards myometrial side. Uterine glands appeared to be of holocrine in nature. The myometrium formed the main bulk of thickness of the uterine wall and consisted of smooth muscle fibers. Three distinct layers namely, stratum submucosum, stratum vasculare and stratum sub- serosum were observed. The perimetrium presented the structure of serous membrane.

Banks (1993) described that the wall of the uterus which was divided into distinct endometrium, myometrium and perimetrium. The morphology of the uterus changed in different phases of the estrus cycle. The endometrium included the tunica mucosa in which lamina propria was lined by simple columnar epithelium. Patches of pseudostratified columnar epithelium may be encountered in the sow and cow. Isolated foci of cuboidal epithelium were noticed in some phases. Uterine glands were simple or branched tubular glands extended into the lamina propria. Their distal ends had a variable degree of coiling that was species-dependant. In ruminants, an area of the lamina propria was highly vascularised and devoid of glands. The caruncular area was devoid of uterine glands. Although there was no tunica submucosa, the peripheral connective tissue was less cellular than the subepithelial. The endometrium was subjected to changes during the estrus cycle. The myometrium consisted of a thick inner circular and outer thin longitudinally oriented coat which continued into the mesometrium. A stratum vasculare occurred between the two layers of smooth muscle. The perimetrium or tunica serosa was typical and continued large number of lymphatic vessels. The cervix was usually glandless. The lining cells of the cervix in cow were highly glandular. Their secretory activity varied with the stages of the estrus cycle and pregnancy. Clear mucus was secreted during estrus and a thick cervical seal was produced during pregnancy. Numerous longitudinal folds imparted the impression that it was glandular. The lamina epithelialis mucosa of the endocervical canal was composed of primarily goblet-like cells but some kinociliated columnar cells may be present. The lamina muscularis was well-developed and rich in elastic fibers.

Ohtani et al. (1993) studied the histological changes in bovine endometrium during the estrous cycle. Endometrial biopsy specimens were obtained from 46 normally cyclic heifers at known stages of their estrous period to show precise characteristic changes. Metrorrhagia was observed on days 0 to 1 (estrus = day 0). Mitoses in glandular epithelium occurred on day 5. Basal vacuolation in the surface epithelium occurred on days 5 to 6. Leukocyte invaded the functional layer on day 7.
Stromal mitoses were observed on days 9 to 12. The results indicated that clinicians need to be aware that histological evaluation is important for the diagnosis of endometrial function and biopsy is useful for this purpose.

Uppal and Roy (2000) conducted histological study on cervix of 24 Murrah buffaloes which were divided into four groups viz. neonatal (up to one month), prepubertal (1.5 to 2 years), cyclic (diestrus) and pregnant (early pregnancy). The lamina epithelialis of cervix of neonatal calves was simple cuboidal which was transforming into simple columnar. In prepubertal and adult animals the epithelium was simple columnar mucinogenic. The epithelial height was more at the base of cervical folds than its apex in all the age groups. In cyclic animals at some locations secretory blebs could also be noticed along the luminal surface of the epithelium. In some cervix large sized glands (ovula nabathi) were present, which might be developed due to occlusion of the cervical glands or ducts resulting in the excess accumulation of mucus. The fibroarchitecture composed of collagen, reticular and elastic fibers. In neonates the tunica muscularis was comprised of inner circular and outer longitudinally arranged smooth muscle fibers; whereas in prepubertal and pubertal animals there was no particular arrangement of muscle fibers which were randomly distributed. The serosa was made up of loose connective tissue lined by simple squamous epithelium with blood vessels, lymphatic and nerve fibers.

Alboghobeish (2000) reported that the endometrium of water buffaloes revealed an increase in the height and secretory activity of epithelial cells during the luteal phase. Cyclic erosion of the surface epithelium was seen in early diestrus. The extravasation of blood, necrosis and de-epithelization as well as edema in the stroma of endometrium were observed during the follicular phase. The branched tubular endometrial glands were not seen in the caruncular area.

Asdell (2002) reported that the outer coat of the uterus was serous in nature which continued with the broad ligaments. Within this there were 3 coats, an outer longitudinal layer, a middle layer and an inner circular layer of unstriated muscle. The inner circular layer was well developed in cervix. The innermost layer of the uterus was endometrium in which thickest layer of connective tissue penetrated by uterine glands which were lined by cuboidal to columnar epithelium of secretory cells. At intervals, there were slightly elevated bosses, the caruncles (cotyledons), which were about 100 in number, arranged irregularly on the inner surface of the endometrium. The caruncular part was devoid of glands. The cervix uteri were the posterior portion
of the uterus which consisted of dense, unstriated muscle. Mucous membrane of cervix was folded and lined by columnar epithelial cells. There were number of longitudinal folds and usually four annular rings, the latter was arranged spirally. At the time of heat, mucus cells were well filled with mucous and the mucous coat was congested. Six days after the heat, the epithelium was uniform in height. Between 8 to 11 days, the surface epithelium tends to be irregular, giving a ragged appearance. On 14th day, the posterior os uteri appeared blanched, dry and constricted. On 17th day, the columnar epithelial cells were larger. On 20th day, there was marked congestion and the os uteri were dilated. The cells of the epithelium were larger than any other stage of estrus cycle.

Trautmann and Fiebiger (2002) studied the histology and cyclical changes in the uterine endometrium of the ruminants. They observed that the endometrial epithelium was of stratified columnar type and lamina propria consisted of abundant reticular fibers with number of cells. They described the uterine glands as simple, branched tubular glands and coiled towards the ends. The glands possessed a lamellar connective tissue and were lined by simple columnar or sometimes ciliated columnar epithelium. Tissue spaces were found between the fibro-elastic gland sheath and the lamina propria. They further stated that, in ruminants the glands were shorter and were present only in diestrus. During first part of diestrus stage or the stage of glandular hyperplasia (in case of cow from 2nd to 14th day of the cycle), they found the maximum development of the glands which became longer and more coiled with profuse secretion. In the second part of the diestrus (in case of cow from 15th to 19th day), they found that the glands were reduced and shorter with shrinkage of mucosa. They also reported the presence of three layers in the myometrium; but the stratum vasculare with many thick walled blood vessels were located within the outer half of the circular muscle which was found outside the stratum vasculare.

Uppal and Roy (2002) reported that the endometrium of cyclic buffalo uterus was made up of dense irregular connective tissue richly supplied by blood capillaries and showed good number of mast cells, lymphocytes, plasma cells and macrophages. Reticular fibres were evident in the basement membrane and also in stroma of the endometrium. Coarse collagen and reticular fibres were seen between endometrial glands, whereas elastic fibres were present mainly in and around the wall of blood vessels. Glands were coiled tubular in the cyclic buffalo. Cytoplasmic blebs were seen in the luminal border of the endometrial glands.
Shahrouz and Mashmolian (2003) studied the histological and histomorphometrical structure of uterus during different stages of estrus cycle. They recorded that, the increase in thickness of myometrium and perimetrium caused by effect of estrogen in the follicular phase. Progesterone improved the epithelial and glandular thicknesses in the luteal phase and further they noticed that, the estrogen also causes branching of the glands. Thus these results confirmed the concept that in the uterus of the buffalo’s estrogen and progesterone effects in both the follicular and luteal phases on the epithelium, glands, myometrium and perimetrium.

Eurell and Frappier (2006) studied the histological structure of uterus and cervix. It underwent a definite sequence of changes during the estrus cycle and pregnancy. They describe that the endometrium was composed structurally and functionally into two different layers. The outer layer, called the functional zone, which degenerated partially or fully after pregnancy or after estrus. A deep layer, the basal zone, persisted after these events and the functional zone was restored from this layer. The surface epithelium of the functional zone was pseudostratified columnar or simple columnar in sows and ruminants. In isolated areas, the epithelium was simple cuboidal further they noticed that the height and structure of the epithelial cells was related to the secretion of ovarian hormones throughout the cycle.

The subepithelium part was richly vascular which consisted of loose connective tissue with many fibrocytes, macrophages and mast cells. Neutrophils, eosinophils, lymphocytes and plasma cells were also present. The deep part of the functional zone was less cellular than that of the superficial part. In ruminants, during estrus, large irregular fluid-filled tissue spaces were present in the functional zone, which was termed as endometrial edema. Simple coiled, branched tubular glands were present throughout the endometrium. The simple columnar glandular epithelium included secretory and nonsecretory ciliated cells. Growth and branching of the glands was noticed during rise in estrogen. In ruminanats, they found the circumscribed thickenings of the endometrium known as caruncles. Approximately 15 caruncles in each of four rows were present in each uterine horn in ruminants, which were dome-shaped in cows. They described the cervix or the neck of the uterus was thick-walled, muscular and rich in elastic fibers. The mucosa-submucosa formed high primary, secondary and tertiary folds. In cows, four large circular and 15-25 longitudinal primary folds, each with many secondary and tertiary folds, were present. Uterine glands did not extend into cervix. The epithelium of cervix was of the simple
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columnar type with many mucigenous cells, including goblet cells. In pregnancy, the mucus was thickened to form the cervical seal. Intraepithelial and simple tubular glands were present in ruminants. The propria-submucosa consisted of dense irregular connective tissue, which became edematous in lose areolar structure during estrus. The tunica muscularis consisted of inner circular and outer longitudinal smooth muscle layers. Elastic fibers were prominent in circular layer. The muscle layer of the cervix was continuous with those of the body of the uterus and vagina. The tunica serosa of the cervix consisted of loose connective tissue covered by mesothelium.

Ghosh (2006) described the histology of the uterus. He recorded that the wall of the uterus was composed of outer serous coat, the perimetrium, middle muscular coat, the myometrium and the inner mucous coat, the endometrium. He observed that perimetrium was continued from peritoneum and covered the whole organ except the lateral borders. They described three layer in the myometrium outer and inner longitudinal and middle circular smooth muscle. They found that the endometrial epithelium was ciliated columnar in horn and columnar in body and cervix and stratified at external os. The epithelial cells were tall during estrus and columnar or cuboidal during postestrus phase. The endometrial glands were coiled tubular and branched, which opened on the endometrial surface but not on the caruncular area. These glands extended up to the inner surface of the myometrium and were lined by columnar cells with occasional cilia.

Schmidt et al. (2006) studied histo-morphology of the uterus and early placenta of the African buffalo (Syncerus caffer) and compared with cattle (Bos taurus). In the histological observations they observed that, the uterine wall comprised of three distinct tissue layers as inner tunica mucosa (endometrium), middle tunica muscularis (myometrium) and outer tunica serosa (perimetrium). The endometrium consisted of the lamina epithelialis (surface epithelium) and the lamina propria mucosae. Dome shaped thickenings of the lamina propria represented caruncles, which were separated from one another by thinner, intercaruncular areas.

The lamina propria was arranged in two layers, as sub-epithelial cellular zone and deeper vascular zone lying immediately adjacent to the tunica muscularis. Simple, branched and coiled tubular glands were visible throughout the lamina propria. They were restricted to deeper layers below the caruncles as the caruncular tissue proper was devoid of glands. Glandular tissue was most abundant in the deeper layers of the lamina propria and less numerous in superficial regions. A simple columnar
epithelium covered most of the surface areas, whereas sometimes simple cuboidal or pseudostratified type was noticed. The epithelium and underlying lamina propria often displayed a wavy appearance in the caruncular areas, resulting in a series of ridges and intervening depressions. Nuclei of the epithelium were generally oval in shape and basally situated. Intra-epithelial lymphocytes were randomly distributed throughout the epithelium.

Bandyopadyay et al. (2007) studied the histology of bovine uterus. The uterus consisted of three layers namely endometrium, myometrium and peritoneum. The thickness and blood supply of the uterus was variable depending on the physiological changes in the reproductive tract. The density of the uterine glands per unit area changed considerably depending upon species, breed and reproductive cycle. These glands were branched and tubular and were increased during gestation period. Under the influence of estrogen during proestrus and estrus, the vascularity in the epithelium was increased. The surface epithelium showed shorter columnar cells and glands were found to grow to some extent. During the luteal phase particularly in diestrus the changes in endometrium were increase in thickness of endometrium, surface epithelium became columnar, the uterine glands were highly developed with multiple branching and initiation of secretory activity. In late diestrus, there was shrinkage of endometrium and regression of uterine glands with drastic reduction of secretory activity. The myometrium was made up of thick inner circular and thin outer longitudinal layer. In between these two layers, blood vessels, lymph ducts, nerves and connective tissue were observed. During pregnancy, the muscular layer increased considerably both in enlargements of cells and also in cell numbers.

Dyce et al. (2010) described the histological structure of the uterus of cow. They observed that uterine wall consist of serosal, muscular and mucosal coats that were known as the perimetrium, myometrium and endometrial, respectively. The serosal covering reached the uterus by extension from the supporting broad ligament. Tunica muscularis was arranged as thin external longitudinal and thicker internal circular layers separated by stratum vascular. External muscle layer, extended (as perimetrium) into the supporting broad ligaments. The endometrium was thick and its surface showed numerous caruncles, where the embryonic membranes were firmly attached during pregnancy. Numerous tubular glands opened on the surface, which was lined by a simple columnar epithelium.
Bacha and Bacha (2012) studied the histology of the uterus of the domestic animals. The wall of the bicornuate uterus was made up of three layers; as the outer perimetrium, middle myometrium and inner endometrium. The epithelium of the endometrium was stratified or pseudostratified type in ruminants. Simple, branched uterine glands extended into the lamina propria. Caruncular region of the endometrium was non-glandular in ruminants. The mucosa of the uterine cervix was elevated into longitudinal folds, some of which were subdivided into secondary and tertiary folds. The epithelial lining was simple columnar with goblet cells. The estrus cycle was consisted of a succession of physiological stages. Proestrus (1st stage) was characterized by endometrial growth. It was followed by estrus, when ovulation occurs. The development of corpus luteum occurred during the, metestrus. Diestrus followed metestrus and coincides with the presence of a fully functional corpus luteum. During this time the development and secretory activity of the endometrial glands was at its peak. Anestrus, a period of sexual inactivity, followed diestrus.

Getty (2012) described the histological of uterus and cervix in bovine. The muscular coat of the uterus was thick. It consisted of an external longitudinal layer and two circular strata. The uterine glands were long and branched which were absent in cervix but thick mucus was secreted by goblet cells. The inner circular layer was thicker in the cervix. The outer layer was continued in the vagina. The mucus membrane of the cervix was pale and glandless and formed numerous folds which obliterated the lumen. At the external uterine orifice, the folds formed rounded prominences arranged circularly, which projected into the cavity of the vagina.

Pathak and Bansal (2012) observed that the endometrial glands were simple or branched tubular glands of which few were coiled distally. They were lined with simple columnar epithelium. These glands were more active during the follicular phase as compared to the luteal phase of estrous cycle. The secretory activity was more pronounced during the luteal phase in buffalo.

Salih and Abass (2014) studied the glands in cervix of black goat they observed the simple tubular, branched glands in the cervix. These cervical glands were lest developed in younger, while more elongated branched glands seen in adults. The simple columnar cells of the surface epithelium extends with the lining of these glands, but were taller with basal oval nuclei. These glands showed further branching in the depth of lamina propria near the muscular layer of the cervix uteri of 3.5 years aged goat.
Karimi *et al.* (2017) described that the uterine wall in Azerbaijan buffalo consist of endometrium, myometrium and preimetrium similar to other mammals. They found that the muscularis mucosa is absent in tunica mucosa of uterus, lamina propria and tunica submucosa is united. The mucosa were lined by pseudostratified epithelium with ciliated cells in some regions, epithelial tissue invaginated to laminae propria submucosa and changed to simple columnar and made uterine glands. Simple tubular and simple coiled tubular gland were observed in lamina propria and tunica submucosa. They also observed many melanocytes in lamina propria and tunica submucosa of uterus of buffalo.

### 2.2 HISTOCHEMISTRY

#### 2.2.1 Oviduct during follicular and luteal phases

**2.2.1.1 Carbohydrates**

Fredricsson (1969) reported that the apical surface of the non-ciliated cells was more or less PAS positive. In the isthmus of rat secretory material seemed to adhere to the cell surface, making microvilli stick together to form a tuft like formation.

Sundaravadanan and Venkataswamy (1973) carried out histological and histochemical study on bovine oviduct. In the oviductal epithelium, they observed Alcian Blue positive activity for presence of acid mucopolysaccharides. They further found quantitative variation in the PAS positive zone in the epithelium of bovine oviduct depending on the estrogen state of body.

Dubois *et al.* (1980) studied tissue concentrations of mast cells and lymphocytes of the bovine oviduct during the estrous cycle. They noticed that the mast cell count of the isthmus was found to be significantly higher than the mast cell count of the ampulla for all stages of the estrous cycle. A significant increase in the mast cell value of the isthmus occurred during metestrous, diestrous and proestrus. In the ampulla, metestrous and diestrous mast cells numbers were significantly higher than mast cell numbers during estrus. They observed that the lymphocyte numbers remained relatively constant in both the ampulla and the isthmus except during diestrous, when ampullary lymphocyte numbers increased significantly. They reported that lymphocytes were observed to migrate through the uterine tube epithelium and mast cells were observed only in the lamina propria.

Bhattacharya (1984) observed high secretory activity of oviducts during follicular phase by high intensity of PAS reaction in normal buffaloes.
Singh and Parkash (1990) recorded PAS and alcian blue positive reactions revealing presence of neutral and acidic mucopolysaccharides on the luminal surface of the ampulla in goats.

Sohi (1992) reported that PAS positive material was synthesized during follicular phase and got secreted during the luteal phase and this process mainly occurs in infundibulum and ampulla. He found no alcinophilia at pH 1.00 but at pH 2.5 a weak alcinophilic material was observed.

Gregorazczuk et al. (2000) studied the two different parts of the porcine fallopian tube with special reference to cyclic changes in the distribution of glycogen particles. During the periovulatory stage of the estrous cycle glycogen granules were observed in the apical cytoplasm of epithelial cells in both the ampulla and isthmus. After the ovulation numerous secretory granules of the polysaccharides were seen in the isthmus. It is possible that glycogen in the preovulatory stage functions as a source of energy for ciliary movement and a nourishment for the ovum. After the ovulation secretory granules of the polysaccharides could be the major source of energy for embryogenesis when the embryo travels down the fallopian tube during the early cleavage stage.

Natarajan et al. (2003) studied the oviduct of buffalo and reported that superior border of epithelial cells showed a consistent Periodic acid Schiff (PAS) positive zone irrespective of different regions of different reproductive phases. The PAS-reaction was more intense in follicular phase than in luteal phase and during pregnancy.

Tienthai et al. (2008) reported a strong intensity of PAS reaction in the epithelium of isthmus and utero-tubal junction during the follicular phase in the oviduct of Thai swamp buffalo.

Ayen et al. (2012) observed that in the oviduct of Azarbaijan buffaloes with toluidine blue staining, mast cells with centrally located nucleus and secretory granules in the cytoplasm are present in the connective tissue of the primary folds, between the muscular fibers in tunica muscularis and serosa. They are especially abundant around blood vessels.

Ozen et al. (2013) observed that, increased Glycosa Aamino Gglycan (GAG) secretion during the estrus phase, was in particular stored in the crypts of the isthmus. Electron microscopic examination revealed that, increased amount of secretory
material, which accumulated in secretory cells during the estrus phase, was stored in two different types of secretory granules in the porcine oviduct.

Katare et al. (2015) found in adult goats that the strong PAS positive reaction towards apical border of epithelium of infundibulum ampulla and isthmus which is more intense during follicular phases than the luteal phase.

Mokhtar (2015) found that the ampullary epithelium shows increase in secretions of neutral, acidic mucopolysaccharide and lipid from the secretory cells at the luteal phase with moderate acid phosphatase activity in cow.

Saleem et al. (2016) during luteal phase, apical blebs with PAS positive material were seen above lining epithelium in the oviduct of goat. The cytoplasm of glandular and lining epithelium showed strong reaction with Alcian blue. Tunica muscularis showed moderate reaction for Alcian blue.

2.2.1.1 Lipids

Abdalla (1968) recorded lipid droplets in the supranuclear part of the tubal epithelial cells of the oviduct in sheep.

Wordinger et al. (1977) observed moderate amounts of lipids in the isthmic epithelial cells usually close to the nucleus. No difference was observed in the lipid contents between ciliated and secretory epithelial cells. They also observed distinct regional differences within the bovine oviduct with respect to cytoplasmic lipid content.

Uhrin (1983) observed that in cow the occurrence of lipids varied slightly during different phases of oestrous cycle.

Sohi (1992) observed that the lipid droplets were associated with the periodic acid schiff positive secretory material evidencing similar regional and cyclic variations in buffalo oviduct.

Mokhtar (2015) identified the lipid droplets by Sudan Black B in the apical portion of the epithelium of ampulla at the luteal phase more than follicular phase in cow.

Saleem et al. (2016) during luteal phase, the cytoplasm of glandular and lining epithelium showed mild reactivity for bound lipids. Tunica muscularis showed mild reaction for bound lipids with Sudan Black B.

2.2.2 Uterus during follicular and luteal phases

Likar and Likar (1964) studied the histochemistry of uterus in bovine at different stages of sexual cycle. They reported that, there was increase in
mucopolysaccharide concentration in the surface epithelium during the follicular phase than in the luteal phase, maximum being at the estrus and minimum at the metestrus. In the uterine glands they observed increased mucopolysaccharide content in cow during the follicular phase.

Larson et al. (1965) studied cyclic histochemical changes in the bovine endometrium. They reported that the highest concentration of PAS-positive material was observed in the epithelial cells at estrus and the lowest on day 8-14 post estrus. Subsequently they estimated the concentration of the endometrial glycogen and found higher in the luteal phase and lower in the estrus. They observed a weak alkaline phosphatase reaction along the distal border of the surface epithelium in uterus of cow during estrus. They did not observe any cyclic variation in the acid phosphatase activity. In the uterine glands they reported an inverse relationship of PAS and alkaline phosphatase activity.

Marinov and Lovell (1967) studied the histochemistry of bovine cervical epithelium. They observed PAS reactions and ALK activity throughout the estrus cycle in the cervical mucosa except on the 7th day.

Marinov and Lovell (1968) studied the histochemistry of bovine uterine epithelium during estrus cycle. They observed a distinct cyclic variation in PAS concentration during estrus cycle of cow and reported that the surface epithelium contained more PAS-positive material during the estrus than in that of diestrus. They also observed highest alkaline phosphatase activity in the uterine epithelium in the mid cycle. They reported that the superficial uterine glands were more reactive for PAS than the basal glands during diestrus.

Larson et al. (1970) studied the histochemical activity and glycogen metabolism in bovine endometrium. They reported the lowest alkaline phosphate activity in the glands during estrus and highest on 8-14 days post estrus. They did not observe cyclic variation in the acid phosphatase activity in the uterine glands.

Wordinger et al. (1970) studied the histochemistry of bovine endometrium. They observed the reaction for neutral mucosubstances which was concentrated in the apical portion of the cells at the time of estrus and glycogen was observed during diestrus. In the uterine glands they also observed diffuse reaction for neutral mucosubstances at the apical border and sulphated mucosubstances throughout the cytoplasm during the metestrus. During the estrus, the neutral mucosubstances occurred only at the apical border and glycogen was altogether absent.
Kalkar (1971) studied histochemical changes in uterus of the Indian buffalo in proestrus stage. He noticed large quantity of glycogen in the surface epithelial cells and distinct in basement membrane by PAS staining in the proestrus stage.

Wordinger et al. (1971) studied the histochemical activities in the bovine endometrium. They recorded the endometrial lining was intensely positive for glycogen but negative on day 15.

Dwivedi and Singh (1972) studied the histochemical changes in the endometrium of Indian buffaloes. They reported that the mild intensity of reaction for PAS-positive material was observed at the apical border of lining epithelium in luteal phase. The alkaline phosphatase activity in the luminal epithelium increased in the luteal phase and decreased in follicular phase. In the glandular epithelium they did not observe any cyclic variation in the alkaline phosphatase and glycogen activity in buffalo.

Sundaravadanan and Venkataswamy (1973b) studied the histochemistry of the bovine uterus during the follicular, luteal, senile, cystic and smooth ovarian conditions. The apical portion of the epithelial cells lining of the endometrium showed PAS-positive zone and it was intense in the follicular and cystic conditions of the ovary. They further reported that in all the groups, the glandular epithelium showed a PAS-positive zone and it was intense in those glands closer to the myometrium. The PAS-positive material was either confined to the apical portion of the cell or uniformly distributed as granules throughout the cytoplasm. PAS-positive material was not stained by Alcian blue either in the surface or glandular epithelium of the uterus.

Wordinger et al. (1973) studied the carbohydrate contents in the cervical mucosa in heifers. The tissue samples were obtained at slaughter from mid-cervix of three heifers at 4th day of proestrus and from the anterior, middle and posterior cervix of two cows at 14th day of proestrus. Non-ciliated cells contained both sulphated and carboxylic acidic mucosubstances which was absent in the columnar ciliated cells. By 14th day of proestrus, the ciliated cells were more prominent, but did not showed stored mucin, whereas, the amount of stored mucin in non-ciliated epithelial cells was greatly reduced.

Sundarvandanan (1974) studied the histochemical changes occurring in the bovine cervix and vagina during the follicular, luteal, senile, cystic and smooth ovarian conditions. In all the ovarian conditions, the apical portion of the epithelial
cells lining the cervix contained PAS positive material, but it showed quantitative variation. It was more in the follicular and cystic conditions and scanty in the luteal, senile and smooth conditions of the ovary. The PAS positive material in all the ovarian conditions was more in the cells situated deeper in the folds than in those closer to the surface.

Fateh El-Bab and El-Naggar (1975) observed that in the surface and glandular epithelium of buffalo cervix at estrus acid mucopolysaccharide materials were maximum while basophilic substances reach their maximum at diestrus. Lipid content were negligible at estrus in the surface and glandular epithelium, but sudanophilic granules appear at diestrus.

Agarwal et al. (1978) studied the histochemical changes in uterus of buffalo. They observed the PAS positive reaction at the apical border of the lining epithelium which was prominent in the follicular phase than in the luteal phase. In the uterine glands PAS-positive activity was increased during estrus.

Raizada et al. (1978) studied the histochemical reactions in cervix of buffalo. They reported the PAS reaction in the cervical epithelium which was maximum during the follicular phase.

Heydon and Adams (1979) studied the histochemistry of the cervix of 16 ewes, 16 female goats and 13 cows. They recorded that the PAS positive material was greatest in the cells containing mucus in cow and least in the ewe. Differences in the total amount of mucus occupied most of the cells in the cervix of the cow, which was confined to the apical half of the cell in the cervix of the goat and ewe.

Ramchandraiah et al. (1980) studied the histochemical changes in the uterus during estrus cycle in ewe. They reported that the intensity of alkaline-phosphatase activity in the uterine luminal epithelium which increased from follicular to luteal phase. The reaction was observed in the entire cell. The reaction was found in the glandular cells during luteal phase, while the reaction was confined either to the luminal or basal portion of the cells during follicular phase.

Sinha (1980) studied the cytochemical changes of bovine endometrium in cattle and buffalo. He reported moderate reaction of PAS positive material along the apical border of the lining epithelium during the estrus.

Singh (1983) studied the histology and histochemistry of the uterus in buffalo during estrus cycle. The samples were divided into 5 groups according to their physiological status viz. group-I (early follicular phase), group-II (late follicular
phase), group-III (early luteal phase), group-IV (mid luteal phase) and group-V (late luteal phase). He recorded that during the early follicular phase the PAS positive diastase resistant material was observed at the apical border of lining epithelium. Rest of the cytoplasm showed mild to homogenous moderate PAS reaction. The intensity of the reaction was maximum during the late follicular phase. It decreased as cycle proceeded towards the luteal phase. Only mild to moderate reaction was observed at the apical border of lining cells during luteal cells.

The connective tissue cells of the lamina propria showed very weak PAS reaction. The reaction was stronger in the superficial propria as compared to the deeper propria. The reaction diminished in the luteal phase. During the early follicular phase, moderate to intense PAS positive material was observed in uterine glands. The superficial glands were more responsive to the PAS stain as compared to deeper glands. The latter were mild reactive for PAS staining. The PAS reaction diminished during the luteal phase. The myometrium showed mild reaction for the PAS staining, which was also diastase resistant. The reaction was mostly confined homogenous in the subsarcolemma. The reaction of acid mucopolysaccharides were inconsistent. The perimetrium was generally inert for the histochemical staining and did not revealed any specific cyclic variation except dilatation of subserosal lymphatics.

Bhattacharya and Saigal (1984) studied the histochemical changes in the uterus of goat during the reproductive cycle. They reported that the PAS-positive material was confined to the luminal border of the glandular epithelia of goat endometrium without appreciable cyclic variations. Relatively stronger PAS reaction was reported at the same sites during metestrus and early diestrus. The caruncles and myometrium showed moderately PAS-positive material, which was remarkable in the connective tissue in between the muscle fibers of the myometrium. The tunica intima of the blood vessels in the uterine wall exhibited moderate to strong PAS-positive reaction.

Malik et al. (1989) studied histochemistry of buffalo uterus affected with uterine torsion. Results showed PAS positive reaction in the basement membrane of uterine and vascular epithelium, infiltrating cells of lamina propria, glandular epithelium, smooth muscle cells of myometrium and mesothelial cells of epimetrium. The myometrium was mostly degenerated and exhausted as indicated by very mild to moderate PAS staining of smooth muscles. Bound lipids were abundant in the
basement membrane in the inflammatory cells of lamina propria and in the blood vascular epithelium.

Uppal and Roy (2008) studied the uterus of 27 buffaloes foetii of different gestational age divided into 3 groups based on the Crown Rump Length (CVR) of the foetii, as group-I (CVR length up to 20 cm), group-II ((CVR length between 20-40 cm)) and group-III (CVR length above 40 cm). They recorded that, moderate to strong reaction of PAS and weak to moderate reaction of PAS/AB was seen in tunica mucosa, muscularis and serosa in all the groups.

Uppal et al. (2009) studied the uterus of 12 buffaloes foetii of different gestational age and divided into 3 groups based on the Crown Rump Length (CVR) of the foetii, as group-I (CVR length up to 20 cm), group-II (CVR length between 20 and 40 cm) and group-III (CVR length above 40 cm). They recorded that the alkaline phosphatase activity in the lamina epithelialis was weak to moderate in group-I, moderate to strong in group- II, but strong in group-III. The blood vessels in the endometrium also showed moderate to strongly positive, whereas myometrium and perimetrium showed weakly positive in all the groups. Thus, they suggested that, an increased activity of alkaline phosphatase in the study during later stages of gestation might be correlated with the increased ionic movement across the epithelium and blood vessels. A generalized weak activity of acid phosphatase was observed in the epithelium, endometrium, myometrium and perimetrium in all the groups, which indicated poor phagocytic activity.

2.3 MICROMETRY
2.3.1 Oviduct during follicular and luteal phases

Ramachandraiah et al. (1980) observed the histological changes in the epithelium during estrus cycle of sheep oviduct. They noted increase in the height of epithelium of oviduct in luteal phase than follicular phase. They opined that the increase in height of epithelium of oviduct may be due to increase in the protein synthesis under progesterone stimulation.

Natarajan et al. (2003b) studied histometric analysis of the oviduct of the buffalo (Bubalus bubalis). They observed numerous mucosal folds of the oviduct in the infundibulum which were less in number in the ampulla and isthmus. They further observed that significant increase in the number of primary folds in the infundibulum during the follicular phase. They stated that the mean height of the epithelial folds in the oviduct gradually decreased from the infundibulum to the isthmus. The height of
the epithelial folds was maximum in the follicular phase and minimum in the luteal phase. They noted maximum cell height in the infundibulum of follicular phase and minimum cell height in isthmus during pregnancy. The epithelial cell height declined gradually from infundibulum to isthmus in all reproductive phases.

Tienthai et al. (2008) reported that the epithelial cell height significantly decreased in the infundibulum and ampulla from the follicular to luteal phases, but not in other regions of oviduct in Thai swamp buffalo.

Ayen et al. (2012) observed that in the oviduct of Azarbaijan buffaloes the number and height of primary and secondary folds decreased from infundibulum to isthmus. The primary folds at follicular phase are higher than those in the luteal phase in three different regions. Mean height of primary folds increase and the mean thickness of tunica muscularis decrease at follicular phase. The mean thickness of mucosa-submucosa at follicular phase was slightly similar to luteal phase.

Mokhtar (2015) found that the mean number and height of primary fold as well as the thickness of the epithelium were increased significantly at the follicular phase in the infundibulum and ampulla of oviduct of cow.

Saleem et al. (2016) observed that in all the three segments of oviduct in Bakerwali goat the height of lining epithelium was significantly higher in luteal phase than follicular phase. The height of epithelium of infundibulum, ampulla and isthmus in follicular phase were 24.75 ± 0.74 μm, 28.92 ± 1.05 μm and 18.46 ± 0.91 μm, in luteal phase 26.29 ± 1.33 μm, 9.76 ± 0.56 μm and 19.28 ± 1.20 μm, respectively. They also observed similar trend in thickness of tunica muscularis of infundibulum was 46.20 ± 2.38 μm, 48.95 ± 1.69 μm; ampulla was 124.30 ± 3.75μm, 260.70 ± 24.62 μm and isthmus was 278.30 ± 18.63 μm, 371.80 ±18.97 μm in follicular and luteal phase, respectively.

2.3.2 Uterus during follicular and luteal phases

Marinov and Lovell (1968) studied the uterine endometrium from 32 cattle during different phases of the estrus cycle. They found that the uterine surface of epithelium was lowest (15 μ) at estrus and increased in size (30 μ) on 6th day. After 16th day of the estrus cycle, the height of epithelium started to decrease. The size of the epithelium of the endometrial glands was lowest at estrus (10 μ) and increased in height (20 μ) at mid-cycle. Glandular hypertrophy was due to the development of the corpus luteum during the cyclic phases.
Hackett and Hafs (1969) observed that the progesterone caused the hypertrophy of the uterine glands during the latter phase of estrus cycle. The maximum epithelial cell height occurred in estrus and ranged from 25.1 to 25.8 μm. There was a marked decrease in cell height in estrus which was ranged from 25.1 to 17.8 μm. Epithelial height was found to be increased significantly during proestrus (P< 0.01) and the increase up to 7th day. They further stated that, there was a second significant increase in endometrial cell height between 11th and 18th days, which were 22.1 ± 2.6 and 24.4 ± 2.5 μm respectively.

EL-Sheikh and Abdelhadi (1970) recorded micrometry of the reproductive tract in the Egyptian buffaloes. The thickness of pseudostratified columnar epithelial layer was 14 to 24 μm. The height of glandular epithelium was 20 to 25 μm in stratum spongiosum and 5 to 7 μm in stratum basalis, which was similar to the surface epithelium.

Kalkar (1971) recorded the micrometrical observations of the uterus of buffaloes in proestrus stage. The surface and glandular epithelial cell height was ranged between 17.9 to 33.9 and 17.7 to 30-85 μm, respectively. The height of the glandular epithelial cells in general was less than that of surface epithelial cells. The diameter of the lumen of the glands towards epithelial side were found more than that of myometrial side. The height of the cervical epithelial cells was ranged from 16.5 to 43.5 μ. He concluded that the height of surface and glandular epithelium of the horn of the uterus was more in proestrus stage than that of anestrus stage. Diameter of the glands was similar in both the stages. There was no difference in the height of the cervical epithelium in both the stage.

Fateh El-Bab and El-Naggar (1975) studied the histology of the cervix uteri of the buffalo cow during the estrus cycle. They recorded that the surface epithelium was of the simple columnar type and reached its maximum height (25–36 μ) at estrus. The cervical glands were branched tubular variety and were restricted to the lateral wall of the cranial part of the cervix.

Janakiraman et al. (1976) studied the endometrial glands in water buffalo heifers and reported that the endometrial glands per unit cross section were highest in number during estrus and lowest during late luteal phase. They also recorded the widest and tortuous uterine endometrial glands with columnar epithelium during luteal phase. The average number of glands in luteal phase was 25.43 ± 3.80 units. Further, they recorded cell height (CH), nuclei height (NH), the ratio of nuclei height
to cell height (NH:CH), gland diameter (GD), lumen diameter (LD) and the ratio of LD:GD. The average values of these parameters were 143.15 ± 3.88 units, 71.53 ± 0.43 units, 1:1.99, 423.82 ± 11.18 units, 136.95 ± 11.66 units and 1: 3.09, respectively.

Singh (1983) recorded the micrometrical observations of the uterus in buffalo during estrus cycle. The samples were divided into 5 groups according to their physiological status i.e. group-I (early follicular phase), group-II (late follicular phase), group-III (early luteal phase), group-IV (mid luteal phase) and group-V (late luteal phase). He recorded that the number of glands/mm$^2$ in group I, II, III, IV and V were 56.74 ± 5.46, 59.58 ± 3.76, 71.35 ± 3.26, 73.13 ± 13.57 and 46.27 ± 5.54, respectively. The diameter of the gland in group I, II, III, IV and V was 70.54 ± 2.30, 73.69 ± 3.44, 91.57 ± 3.22, 99.87 ± 3.57 and 61.03 ± 1.81 μ, respectively. The diameter of the lumen of the gland in group I, II, III, IV and V was 24.45 ± 0.80, 19.81 ± 0.92, 26.60 ± 0.96, 27.30 ± 0.96 and 20.67 ± 0.47 μ, respectively. The glandular epithelial height in group I, II, III, IV and V was 22.81 ± 0.50, 26.96 ± 0.72, 32.48 ± 0.59, 36.17 ± 0.44 and 19.31 ± 0.62 μ, respectively.

Singh and Sharma (1985) observed the progressive and retrogressive changes in the endometrial glands in different phases of the estrus cycle in the Murrah buffalo. They found that, the number of glands per unit of cross section was maximum (71.35 glands/mm$^2$) in the mid luteal phase and minimum (46.27 glands/mm$^2$) in the late luteal phase. The number of glands per mm$^2$ of the endometrium increased constantly from early follicular phase to mid luteal phase. The diameter of the glands and lumen in mid luteal phase as 99.87 ± 3.57 and 27.30 ± 0.96 μm and in late luteal phase as 61.63 ± 1.81 and 20.67 ± 1.81 μm, respectively. They measured the glandular epithelial height in early luteal, mid luteal and late luteal phase as 32.48 ± 0.59, 36.17 ± 0.44 and 19.31 ± 0.62 μm, respectively. They concluded that, the glandular hypertrophy was associated with the cellular hypertrophy due to the accumulation of secretory products in the luteal phase under the influence of progesterone.

Chavan (1987) recorded micrometrical observations of the uterine horns in Murrah buffaloes. The average surface epithelial cell height in left and right horn was 23.25 ± 0.38 and 23.62 ± 0.35 μ, respectively. The average glandular epithelial cell height in left and right horn was 24.21 ± 0.27 and 25.85 ± 0.26 μ, respectively. The average gland diameter in left and right horn was 118.02 ± 2.56 and 120.05 ± 2.86 μ, respectively. The average gland lumen diameter in left and right horn was 50.97 ±
1.95 and 53.33 ± 2.21 μ, respectively. Ratio of average gland diameter to average gland lumen diameter was 2.33:1 and 2.27:1. The average thickness of lamina propria in left and right horn was 1587.24 ± 55.12 and 1620.58 ± 63.79 μ, respectively.

Pandya et al. (1993) studied histomorphological structure of uterus in Surti buffaloes during various phases of estrus cycle. The tissue pieces were taken from cranial 1/3rd part of uterine horn of non ovulated side. In endometrium, the uterine epithelium was simple columnar type with patches of pseudostratified columnar epithelium. Proestrus and estrus showed tall columnar cells, while metestrus and diestrus showed low columnar cells. The thickness of epithelium was more during proestrus. The thickness of endometrium was found to be minimum in estrus and maximum in diestrus phase. The height of glandular epithelium was less during proestrus and more during diestrus phase. The total number of uterine glands per unit area was minimum in proestrus and maximum in estrus. The uterine glands gradually decreased in number from estrus to diestrus. The lumen diameter of uterine gland was found to be smaller in estrus and larger in metestrus. The thickness of entire myometrium was found to be maximum in diestrus phase and minimum in estrus phase. The thickness of circular muscle layer was less in proestrus phase and more on diestrus phase. The thickness of os stratum vasculare was maximum in proestrus and minimum in metestrus phase. The longitudinal muscle layer showed similar trend to that of entire myometrium, which was thicker in diestrus phase and less in estrus phase. The change in thickness of perimetrium was more in thickness in diestrus and less in estrus phase and difference were found to be significant.

Alboghobeish (2000) reported that the endometrium of water buffaloes revealed an increase in the height and secretory activity of epithelial cells during the luteal phase. The number of the superficial glands were more during luteal phase (69.8 ± 8.1 glands/mm²) than during follicular phase (53.6 ± 7.8 glands/mm²). The diameter of the glands at follicular phase (54.8 ± 6.9μ) was lower than the luteal phase (85.9 ± 8.6μ).

Trautmann and Fiebiger (2002) studied the histology and cyclical changes in the uterine endometrium of the ruminants. They recorded that, in ruminants the glands were shorter and measuring 0.1 to 0.2 mm in length which were present only in diestrus.
Schmidt et al. (2006) studied histo-morphology of the uterus and early placenta of the African buffalo (*Syncerus caffer*) and compared with cattle (*Bos taurus*). Glandular tissue was most abundant in the deeper layers of the lamina propria (average glandular diameter 22.4 μm), less numerous within more superficial regions (average glandular diameter 32.7 μm). The average epithelial height was 26.0 and 13.8 μm in caruncular and intercaruncular areas.

Wang et al. (2007) described a digital technique for uterine morphometry and its application to endometrial structure during the bovine estrous cycle. Neither the number nor the size of uterine gland ducts changed during the cycle but there was reduction in total endometrial area from days 0 to 8 after estrus which led to an increase in the proportion of the endometrium occupied by gland ducts (gland duct density). This effect on day 8 was maintained to day 16. When endometrial morphology was related to circulating progesterone concentrations on days 5 and 8 of the luteal phase, no relationships were found on day 5, but on day 8, a high progesterone concentration was associated with an increased number of gland ducts. The results suggested that contrary to expectation, endometrial glands did not grow and regress during the estrous cycle, although cyclic changes in endometrial area was controlled by progesterone which lead to changes in gland duct density.

Shahrooz et al. (2008) studied the micrometry of cervix collected from 20 healthy non-pregnant buffaloes and grouped into follicular phase and luteal phase, on the basis of ovary. The samples were taken from anterior, middle and posterior regions of cervix. The thickness of epithelium was significantly (P<0.05) increased in luteal phase. Mean thickness of mucosa-submucosa layers in middle and posterior region was 290.4 ± 12.69 and 283.14 ± 16.49 μm, respectively. In follicular phase it was significantly (P < 0.05) more than luteal phase. Mean thickness of tunica muscularis in follicular phase in anterior region of cervix was 3325.28 ± 286.69 μm, which was significantly (P < 0.05) increased. This study also revealed that the mean distribution of mast cells in the luteal phase was 0.53 ± 0.02, which was significantly (P < 0.001) more than follicular phase. These changes might be related to the fluctuation of estrogen and progesterone hormones and distribution of mast cells.

Tienthai and Sajjarengpong (2013) studied the morphological changes in the endometrium of 20 swamp buffalo at follicular and mid-luteal phases. The results revealed that the height of the endometrial epithelium, the number of superficial
endometrial glands and the number of capillaries were significantly ($p < 0.05$) greater at the follicular phase.

2.4 SCANNING ELECTRON MICROSCOPY

2.4.1 Oviduct during follicular and luteal phases

Hafez (1972) studied the reproductive tract of rabbit and monkey under the scanning electron microscope. He noticed ciliated and non-ciliated secretory cells in the epithelium of fimbriae of oviduct. Ciliated cells were covered by kinocilia which overlapped the surface of secretory cells. He found dome shaped surface of non-ciliated cells covered with secretory microvilli or microridges with junctional complexes between adjacent cells. He noticed remarkable morphological differences between the tissue organization of the mucosa of the same organ in the two species. He noticed abundant ciliated cells especially in the fimbriae. The percentage of ciliated cells decreased gradually from the ampulla to the isthmus.

Hafez and Kanagawa (1973) conducted scanning electron microscopy of bovine reproductive tract in female. They observed that the epithelium of oviduct was made up of ciliated and secretory cells. Ciliated cells were covered by kinocilia which overlapped the concave surface of secretory cells. The non-ciliated cells with dome like surface were covered with secretory microvilli. They noted honey comb like structure on the surface of oviduct. Ciliated cells were most abundant in the fimbriae. The proportion of ciliated cells decreased gradually from the ampulla to the isthmus. Ciliated cells, found singly or in groups, were arranged in rows or a mosaic pattern. They observed that the tissue organization of the epithelium and surface morphology of secretory cells varied in different parts of the ampulla and isthmus. The mucosal folds of the fimbriae were arranged in an irregular pattern and were composed of very high percent of ciliated cells. The long kinocilia were overlapping the surface of non-ciliated cells.

Stalheim et al. (1975) carried out scanning electron microscopy of the bovine, equine, porcine, and caprine oviduct. They noticed secretory and ciliated cells as the main types of epithelial cells. Both types were more active during estrus. Cilia were observed in both the infundibular and the ampular parts of the uterine tube, but ciliated cells were more numerous than secretory cells on the surface of the fimbriae.

Arthur et al. (1976) examined the luminal surfaces of epithelial cells of oviduct and uterus from 16 sows at days 1, 3 and 9 of estrous cycle with the scanning electron microscope. Ciliated cells were numerous in the fimbria, ampulla and
isthmus, less abundant in the utero-tubal junction or uterine body and very rare in the cervix. At estrus, ciliated cells predominated the oviduct. At day 3 or day 9 of the cycle, secretory cells were well developed in the fimbria, ampulla and isthmus. These secretory cells became more densely populated with microvilli than those found in uterine body or cervix. No apparent deciliation of ciliated cells was observed in these stages of the estrous cycle.

Wu et al. (1976) conducted scanning electron microscopic study of the porcine oviduct and uterus. They noticed that ciliated cells were numerous in the fimbria, ampulla and isthmus. At estrus, ciliated cells predominated the oviduct. At day-3 or day-9 of the cycle, secretory cells were well developed in the fimbria, ampulla and isthmus. These secretory cells became more densely populated with microvilli than those found in uterine body or cervix. They did not observe apparent deciliation of ciliated cells in these stages of the estrous cycle. They reported regional difference of sensitivity of the porcine reproductive epithelium in its response to endogenous hormonal effect.

Nayak (1977) studied the camel uterine tube by SEM in all the stages of estrus cycle and clearly mentioned that pronounced alterations in the 3-dimensional surface features of ciliated and secretory cells during estrus and post ovulatory phases were not apparent.

Kuhnel and Busch (1979) observed surface morphology of the rabbit uterus and oviduct during estrus. They found that the oviductal mucosa in the ampullary region formed tall, unbranching, longitudinally aligned folds. However they did not find secondary and tertiary folds. A complicated system of low lying slanting, diagonal mucosal ledges was formed between the tall longitudinal folds. They connected neighboring longitudinal folds together.

Myers et al. (1984) noted comparative aging changes in canine uterine tubes (oviducts) by electron microscopy. They reported that subdivision of mucosal folds, invaginations of mucosa into the entire length of the folds and height of the folds increased with age whereas the width of the mucosal folds had decreased. They reported that variable amount of an amorphous material presumably a secretory product enveloped microvilli of most nonciliated cells in infundibulum. They found that complete dedifferentiation of epithelium of the uterine tube ampulla and isthmus to nonciliated cells in a few aged dogs resembled changes in postmenopausal women. In a late prepubertal dog, early ciliation of ampulla and isthmus began before first
estrus. They noticed nonciliated cells with a single central cellular projection in all segments and all age groups.

Hunter et al. (1991) conducted a scanning electron microscopic study on distribution, morphology and epithelial interactions of bovine spermatozoa in the oviduct before and after ovulation. They noticed that majority of spermatozoa in this region showed strands and droplets of secretory material distributed over the anterior portion of an intact head before ovulation, whereas distribution of material over the post-nuclear cap of spermatozoa close to vesiculation or already acrosome-reacted was characteristic of the post-ovulatory situation. They opined that in conjunction with a narrow lumen and viscous secretions in the caudal isthmus, microvilli may thus serve to regulate periovulatory sperm progression towards the site of fertilization and be the basis of intermittent phases of adhesion to the oviduct epithelium as seen by phase-contrast microscopy. They further opined that although cilia do not similarly engage the heads of bull spermatozoa, they may act to regulate progression of capacitated spermatozoa by contacting the principal piece of the flagellum.

Abe and Oikawa (1992) studied oviductal epithelium of the prolific Chinese meishan pig at follicular and luteal phases by scanning electron microscopy. They observed marked cyclic changes on the surfaces of cells in the fimbriae and ampulla but found little change in the isthmus. The cells of the fimbrial epithelium in the follicular phase were densely ciliated, and the cilia partially concealed the bulbous processes of the secretory cells. In the luteal phase, the secretory cells predominated in the epithelium and most of the ciliated cells were hidden by the processes of the secretory cells. The ampullar epithelium showed similar changes, but to a lesser extent. In the isthmus, the secretory cells had many microvilli on their bulbous processes at the follicular phase, but these cells were flat with few short microvilli during the luteal phase. Conspicuous solitary cilia protruded from the surface of secretory cells in the fimbriae and ampulla during the luteal phase. They reported regional variations in the cyclic changes associated with the oviductal epithelial cells of the Chinese meishan pig.

Abe et al. (1993) examined the luminal surfaces of epithelial cells in various regions of the oviducts of the goat at the follicular and luteal phases of the estrous cycle by scanning electron microscopy. The epithelium of the fimbriae ampulla, and ampullar-isthmic junction of oviducts in the follicular phase was extensively ciliated the cilia usually extended above the apices of the nonciliated cells. They were uniform
in length and evenly distributed. At higher magnification, the nonciliated cells were gently rounded on their apical surfaces. Numerous microvilli protruded from the apical surfaces of nonciliated cells. In the isthmus and at the uterotubal junction, the apical surfaces of the non-ciliated cells were flat or gently rounded at both phases of the estrous cycle. In the luteal phase, in fimbriae the bulbous processes of nonciliated cells predominated in the epithelium. The majority of the processes of nonciliated cells were elliptical in shape and were of a variety of sizes. The cilia appeared to be partly hidden below the bulbous processes of nonciliated cells. Most of the processes of nonciliated cells lacked microvilli. At the luteal phase, the epithelium of the ampulla was entirely covered by the bulbous processes of nonciliated cells. The cilia were concealed by nonciliated cells as the bulbous processes of the nonciliated cells extended beyond the tips of the cilia. Most of the processes of the nonciliated cells were elliptical in shape and varied in size. Sometimes the apical protrusions appeared to be only tenuously attached to the underlying cells. The microvilli on the bulbous processes of nonciliated cells were rather stubby.

Abe and Oikawa (1993) observed oviductal epithelial cells from cows at follicular and luteal phases by scanning electron microscopy. They found marked cyclic changes on the surface of the epithelium in the fimbriae and ampulla, but few changes were found in the isthmus and uterotubal junction. The epithelium of the fimbriae and ampulla of oviduct in the follicular phase were densely ciliated, and the cilia concealed the apical processes of the nonciliated cells. In the luteal phase, the nonciliated cells predominated in the epithelium and most of the ciliated cells were hidden by the bulbous processes of the nonciliated cells. The epithelium of the ampullar-isthmic junction showed similar changes, but to a lesser extent. In the isthmus, the apical surfaces of the nonciliated cells were flat or gently rounded during the estrous cycle. They noticed significant decrease in mean percentage of ciliated cells in the fimbriae and ampulla at the luteal phase, but not in the other regions. The height of ciliated cells decreased dramatically in the fimbriae, ampulla and ampullar-isthmic junction at the luteal phase. The height of nonciliated cells decreased significantly in the ampullar-isthmic junction and isthmus at the luteal phase, but not in the fimbriae and ampullae. They concluded that there are regional variations and cellular differences in the cyclic changes associated with the oviductal epithelial cells in the cow.
Abe et al. (1999) observed the structure of goat oviductal secretory cells at follicular and luteal phases of the estrous cycle. They distinguished ciliated and secretory cells as two distinct cell types in epithelium of all regions of goat oviduct. During luteal phase, secretory cells in both fimbrial and ampullar regions displayed slender shape. They noticed various degrees of protrusion at the apices of these cells. They revealed no difference in the morphology of isthmic epithelial cells between follicular and luteal phases. They noted that the ciliated cells were more abundant in the fimbrial and ampullary epithelium than those in the isthmic region. They further observed that the height of both ciliated and secretory cells of all regions was reduced at the luteal phase when compared with the follicular phase. In the fimbria and ampulla at luteal phase, the height of secretory cells was significantly higher than that of ciliated cells.

Kamaci et al. (1999) observed isthmic epithelial cells from the human fallopian tubes at follicular phase by light and scanning electron microscopes. They observed that the lumen of the isthmus was lined by simple ciliated columnar cells, nonciliated secretory cells, few peg cells and reserves cells. They recorded more number of ciliated cells than that of nonciliated cells. Microvilli in nonciliated cells were numerous while the long cilia clusters were abundant on the upper surface of ciliated cells. They also noticed some pits among the cells.

Yániz et al. (2000) studied the functional anatomy of bovine oviductal mucosa. They noticed that the mucosa of the wide side possessed a system of low interconnected cords that converge distally forming primary folds. The folds on the narrow side started sharply from the free margin and fuse toward the ostium abdominale. They reported that areas between folds throughout the lumen of the oviduct show a high degree of complex organization. Interfold spaces were occupied by secondary and small interconnected folds which join to form a system of cul-de-sacs. Marked variations were observed by them in the oviductal epithelium depending on the oviductal segment, basal or apical areas of the folds and phase of the oestrous cycle. Near to the time of ovulation, numerous spermatozoa were found in the periphery of the caudal isthmus within pockets of basal interfold areas, as well as within pockets and cul-de-sacs of the tubo uterine junction. They reported that the topography of the oviduct provided a complex system of regulation which may influence not only the passage of gametes and/or embryos, but also movement of fluid within the oviductal canal.
Areekijseree (2003) noted scanning electron microscopic observations of porcine ampullary oviductal epithelial cells. He noted that the porcine ampullary oviductal epithelial cells contained high number of tall ciliated cells at the follicular phase whereas during the luteal phase consisted of lesser number and were filled up with numerous round nonciliated cells with short microvilli on their apical border. He further reported that the change of the epithelial morphology in the porcine ampullary oviducts during the estrous cycle seems to suit their functions in the reproductive process.

Yaniz et al. (2006) conducted scanning electron microscopic study of the functional anatomy of the porcine oviductal mucosa. They observed that the mucosa was more complex in the narrow side, showing numerous and tortuous longitudinal primary folds, while the mucosa became simpler in the wide side. Areas between folds throughout the lumen of the oviduct showed a high-degree of complexity. Interfold spaces were occupied by a system of irregular grooves and pockets, with the presence of basal crypts in the caudal oviduct. They further observed marked variations in the oviductal epithelium depending on the oviductal segment, basal or apical areas of the folds and phase of the estrous cycle. Cyclical changes were noticed in the infundibulum and ampulla with prominent and numerous ciliated cells lined apical areas of the folds in the follicular phase; whereas secretory cells were predominant throughout all areas of epithelial surface in the luteal phase. The estrous cycle phase appeared do not affect the epithelial population cells of the caudal segments of the oviduct. Ciliated and secretory cells were uniformly lined apical and basal areas of the folds. They reported that the topography of the oviduct provides a complex system of regulation, which may influence not only the passage of cells, but also movement of fluid within the oviductal canal.

Kumar et al. (2008) observed that the mucosa of the fimbria and isthmus was thrown into large number of longitudinal folds being connected each other by transversely placed folds. The epithelium of the oviduct during follicular phase was lined with ciliated and non-ciliated cells. The ciliated cells were comparatively more in number than non-ciliated cells. The distribution of these cells and their concentration and characters appeared to vary in different segments of the oviduct of buffalo. In fimbria non-ciliated cells were isolated and distributed among the ciliated cells had very small microvillus processes which were short, thick and stubby in appearance. In ampulla giant microvillus processes are present on few non-ciliated
cells. In isthmus part non-ciliated cells were placed in form of group. Some of them had giant single microvillus processes on their surface.

Tienthai and Sajjarengpong (2008) reported that the epithelia of infundibulum and ampulla were entirely covered with the bulbous cytoplasmic processes which were protruded beyond the cilia of ciliated cells. Most of bulbous processes were elliptical in shape, a bit irregular on their surface and lacking of microvilli. In isthmus and UTJ, cilia were irregularly distributed on the epithelium and shown a variety of lengths and orientations. Furthermore, the epithelial cells with no cilia which were expected as the secretory cells in UTJ were more swelling than those of isthmus and these cells also lacked off microvilli covered on the surface.

Tienthai et al. (2009) reported that the epithelium of infundibulum and ampulla were densely covered with ciliated cells whose cilia concealed the apical processes of the secretory cells during follicular phase. In contrast, the secretory cells dominated in the epithelium at the luteal phase and most of the ciliated cells were hidden by the bulbous processes of these cells. In the isthmus and UTJ at the follicular and luteal phases, the secretory cells were almost flat or gently rounded and covered with numerous microvilli at their apical surface in the oviducts of Thai swamp buffalo.

Pathak et al. (2012a) studies the mucosal surfaces of the oviduct of five sheep at luteal phase under the Scanning Electron Microscope (SEM) and observed that the oviduct mucosa was thrown into large number of longitudinal folds. The folds were lined with ciliated and nonciliated cells. The bunch of cilia was present on the apices of ciliated cells. Few nonciliated cells interspersed within the group of ciliated cells were observed in infundibulum. In ampulla, the secretory cells equaled in number to the ciliated cells or outnumbered them. Secretory masses of different shape and sizes were spread over the ciliated and secretory cells. In Isthmus large number of secretory cells with few ciliated cells was present.

Sharma et al. (2013) studied the morphological variations in the isthmus of goat oviduct during follicular and luteal phases of oestrous cycle. They observed the irregular distribution of ciliated cells on the isthmic epithelium during follicular phase and few secretory cells possessed bulbous apical processes which were concealed by the cilia. The secretory cells were attached to the basal lamina and were characterized by the presence of secretory granules, numerous ribosomes, extensive smooth endoplasmic reticulum, well developed Golgi zones in the cytoplasm, and a
microvillus luminal surface. They explain that the results were of great help in explaining different bottlenecks of gamete interaction, maturation, fertilization, and early embryo development.

Helal et al. (2015) reported that the mucosa of the infundibulum of buffalo was distinguished by small cords, which converged distally forming primary longitudinal folds and then secondary folds ran obliquely from the lateral walls of these folds and branching toward the basal areas between folds to form cul-de-sacs and pockets. Frequent divergences or convergences or interconnections of folds were observed in the ampulla, more observed at ampullary-isthmic junction, and less frequent in the isthmus. The isthmic mucosa was characterized by folds, ridges, grooves and deep cul-de-sacs or pockets. The ciliated non secretory cells were extensive during the follicular phase, while nonciliated secretory cells were extensive with several bulbous apical processes and large numbers of cilia were hidden during the luteal phase.

Sharma et al. (2015) observed that the luminal surface of ampulla marked cyclic and regional differences. The tunica mucosa of ampulla was characterized by presence of longitudinal mucosal folds throughout the length, presenting expensive secondary and tertiary branches in the follicular phase. Whereas luteal phase possessed primary and secondary branching pattern. The width of mucosal folds and percentage of ciliated cells showed significant decrease along with significant increase in the thickness of submucosa from follicular phase to luteal phase. In follicular phase, the epithelial surface was richly ciliated with uniform length and even distribution. The cilia were found to conceal the apical processes of the non-ciliated cells. The non-ciliated cells possessed microvilli with varied length on their apical surfaces. The secretory cells were gently round and bulbous on their apical surfaces with presence of micro ridges. During the luteal phase of the estrous cycle, the ampullary region was found to be covered by the bulbous epithelial processes of secretory cells that concealed cilia. The apical surface of the secretory cells was covered by microvilli of varied length, a solitary thick cilium was also observed in few cases. Varied degree of ciliation, rosette morphology and zietic blebs along with pinching off of the apical portions of the secretory cells were also observed on the epithelia.
2.4.2 Uterus during follicular and luteal phases

Wordinger et al. (1973) studied the ultrastructure of the cervical mucosa in heifers. The tissue samples were collected from the mid-cervix of three heifers at 4\textsuperscript{th} proestrus day and from the anterior, middle and posterior cervix of two cows at 14\textsuperscript{th} proestrus day. The simple columnar epithelial cells contained abundant mucin in the supranuclear region at 4\textsuperscript{th} proestrus day. The material appeared relatively electron translucent in micrographs but contained some dense staining material within the mucin. Rough endoplasmic reticulum was frequently seen in close proximity to the stored mucin. A Golgi complex was usually situated in close proximity to the stored mucin. By 14\textsuperscript{th} proestrus day, the amount of stored mucin was greatly reduced but similar in density. The constriction of the ciliated cells was observed at 4\textsuperscript{th} proestrus day but not as evident. Numerous cilia with basal bodies within the cell were obvious and the nuclei of these cells were centrally located. Cytoplasmic projections were usually evident among the cilia. Cross section of the cilia clearly revealed the presence of the typical 9+2 arrangement of filaments associated with a motile cilium.

Fathalla et al. (1975) observed biopsy samples of bovine uterus from normal cyclic cows under scanning electron microscopy. Same tissues were routinely processed for paraffin sectioning and re-examined with the light microscope. The surface of the endometrium was well defined with SEM. The section of the submucosa was equally well defined but it was less informative for glandular epithelium. The surface of the acinus could be seen whereas the lumen and the interior of the gland could not be appreciated. The endometrial surface consisted of nonciliated epithelium. Individual cells were connected by intercellular bridges. In cross section, the epithelium was columnar type and relatively intact. Glandular proliferation in an adjacent part to the zona compactum was furnished morphological proof of the biopsy taken during the luteal phase. The surface appearance of the uterine cervical junction under low magnification could be seen. The epithelium of the two areas differed from each other. They reported that scanning electron microscopy could give only surface structure and not the other part of the section.

Hafez (1980) studied the scanning electron microscopic structure of the uterus in cattle they found that the endometrium was characterized by the presence of numerous openings on the endometrial glands. Ciliated cells were less in the endometrium than the oviductal epithelium. Large cytoplasmic projections were noted at the apical membrane of the nonciliated cells. The length shapes and interbranching
of apical microvilli varies throughout the estrus cycle. The degenerated cells were found at random in different stages of the estrus cycle. The cervical mucosa was made up of two types of columnar ciliated cells as ciliated cells with kinocilia and non-ciliated secretory cells which contained massive number of secretory granules. The greatest secretory activity of these cells was occurred in estrus.

Almeida et al. (1986) carried out a scanning and transmission electron microscopic study of the bovine endometrial epithelium on 6 and 7 days post-breeding. The average number of ciliated cells found in the luminal surface of repeat-breeder cows which were lower than that of cows with normal fertility history, although the differences were not highly significant (P < 0.1).

Guillomot and Guay (1982) studied the ultrastructural features of the surfaces epithelium of uterus and trophoblast during the embryo attachment in the cow. Apical cytoplasmic protrusions were observed on the uterine cell surface from cyclic animals between 12 and 6 days during the luteal phase and disappeared thereafter. However, in pregnant animals, these cytoplasmic protrusions were observed until 21 days (attachment stage). These structures suggested that the uterine cells possessed secretory and/or endocytotic properties. Before the attachment stage the trophoblastic cell surface was uniformly covered by slender microvilli. At the beginning of conceptus attachment, the microvilli disappeared and the trophoblastic cell surface became smooth. The areas of the conceptus facing uterine gland openings, papillae were developed and filled the glandular lumen. They interpreted that the conceptus was immobilized on the uterine epithelium and/or a histotrophical mechanism started for absorbing glandular secretory products.

Schmidt et al. (2006) studied the histo-morphology of the uterus and early placenta of the African buffalo (Syncerus caffer) and compared with the cattle (Bos taurus). In SEM, endometrial caruncles were clearly identifiable as round to ovoid, elevated areas which were devoid of gland openings. Cellular ridges gave the net-like caruncular surface. Ridges were consisted of large, bulging, elongated cells which were distinctly different from surrounding flat, hexagonal epithelial cells. The latter measured approximately 5 μm in diameter whereas ridge cells were approximately 13 to 22 μm in length and 4 μm in width. Ridges were frequently interconnected by incompletely surrounding hollow normal cells in one animal and completely encircling variable sized depressions (30 - 100 μm inner diameter) in the other animal. Intercaruncular areas displayed a relatively smooth surface with numerous, unevenly
distributed round to ovoid gland openings. In one animal large numbers of ciliated cells were randomly distributed throughout intercaruncular areas, whereas in the other, they were restricted to the vicinity of the gland openings. Surface epithelial cells were similar in both caruncular and intercaruncular areas. Light and dark staining columnar cells rested on a straight or slightly undulating basement membrane. The apical surface displayed numerous, approximately 0.7 μm long microvilli. Cilia were exclusively observed on some light cells in the intercaruncular areas. Luminal content was sparse and glandular ducts opened vertically or at an oblique angle on the luminal surface. The main difference between the surface and glandular epithelia was the occurrence of abundant ciliated cells in the glandular epithelium. Within the glandular epithelium, non-ciliated cells contained more secretory vesicles beneath the luminal surface than the ciliated cells.

Pathak et al. (2008) observed that endometrial surface of body was less folded as compared to the horns in the uterus of sheep during follicular and luteal phases. The apical part of luminal epithelial cells of corpus uteri was flat and the cells often formed a pattern of hexagonal structure. Epithelium was composed of prociliated, ciliated and secretory cells. Body contained more ciliated cells than the horn of uterus. Ciliated and prociliated cells were more in follicular phase as compared to luteal phase. The secretory cells had microvillous processes and apical blebs. Cervix uteri had complex, deep, narrow folds with small crypts, which were more complex near the internal os. It was also lined with ciliated and secretory cells. Internal os area contained more ciliated cells than the external os area. In the follicular phase cervix had more of ciliated cells as compared to that of luteal phase.

Tienthai and Sajjarengpong (2010) studied the morphology of uterine epithelium in Thai swamp buffalo in follicular and luteal phases by scanning electron microscopy. In follicular phase, the uterine epithelial surface depicted a cobblestone image. Numerous microvilli were covered the epithelial cells and ciliated cells were scarcely found among these cells. Most of epithelial cells were convex and separated from each other by cell borders locating at deep level. Surface of the endometrium in one buffalo were present Ovoid or spherical secretory protrusions. Epithelial surfaces were flat with few microvilli and the cell boundaries were prominent which were protruding into the lumen in luteal phase. They suggested that the estrogen caused an increase in length and number of microvilli including the amount of secretory droplets.
while the progesterone affected the uterine epithelial cell flattening and shortening of microvilli in Thai swamp buffalo uterine horn.

Tienthai and Sajjarengpong (2013) studied the morphological changes in the endometrium of 20 swamp buffalo at follicular and mid luteal phases. The results revealed that the height of the endometrial epithelium, the number of superficial endometrial glands and the number of capillaries were significantly ($P < 0.05$) greater at the follicular phase. The ciliated and secretory cells with different patterns, i.e. abundant microvilli on the apical part or secretory protrusion in various degrees, distinctly increased at the follicular phase. In the meantime, numerous secretory cells with stubby microvilli were covered throughout the endometrial surface with secretory vesicles on endometrial glandular orifices at the mid-luteal phase in which the ciliated cells were sparsely seen.

Pathak et al. (2017) studied the uterine horn, body and cervix of buffalo during follicular and luteal phase of estrous cycle under scanning electron microscope. They observed that the luminal surface of uterus was folded into broad ridges and folds, surface was lined with ciliated and non-ciliated cells. Secretory and non-secretory were the two types of non-ciliated cells. They found that the non-ciliated cells was the main cell population in both follicular and luteal phases of estrous cycle. The number of ciliated cells were less during follicular phase while more number of secretory cells were observed during luteal phase. Glandular opening were observed on the surface of endometrium. Ciliated cells had many kinocilia during the follicular phase. They observed that the cervical surface was highly folded with ridges and deep crypts these ridges consist of cell apices that alternate with deep folds or crypts. Ciliated cells were found on posterior region of the cervix surrounded by several non-ciliated cells having short microvilli on their surface.